Antenna Theory

By

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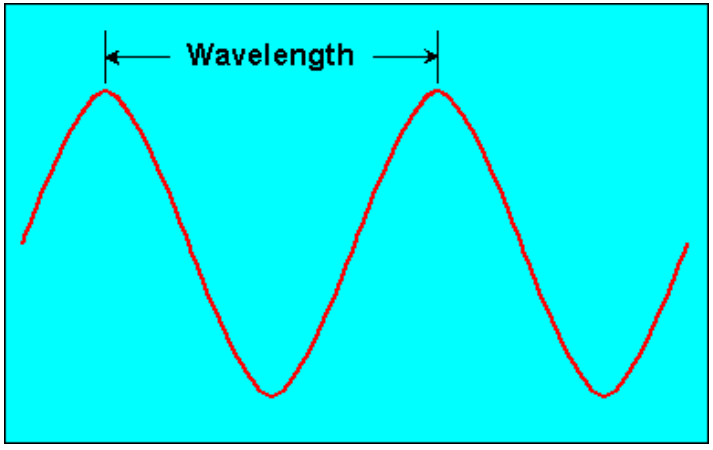
Radio Frequency
RF and Wavelength

Radio Frequency (RF) is a term that refers to an alternating current having characteristics such that, if the current is input to an antenna, an electromagnetic field is generated.

The RF-field has a wavelength that is inversely proportional to the frequency



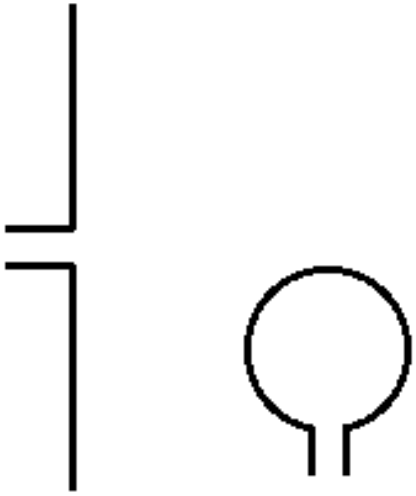
Wavelength (lamda) = 299 792 458 / f

Antenna Basics
What's an antenna?

Antenna : transitional structure between a wave, in free-space and a guiding device.

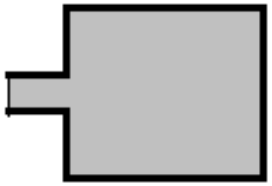
- Part of the transmitting/receiving system which is designed to radiate or receive electromagnetic waves
- Most antennas are resonant devices, which operates over a relative narrow frequency band
- Has to be tuned to the same frequency as the radio system which it is connected to operates in

Different types of antennas

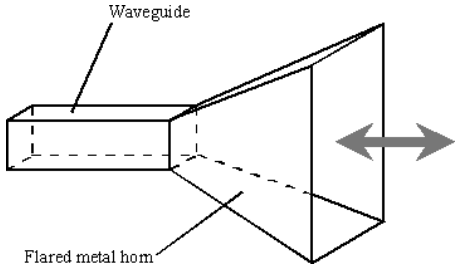


Dipole

Loop



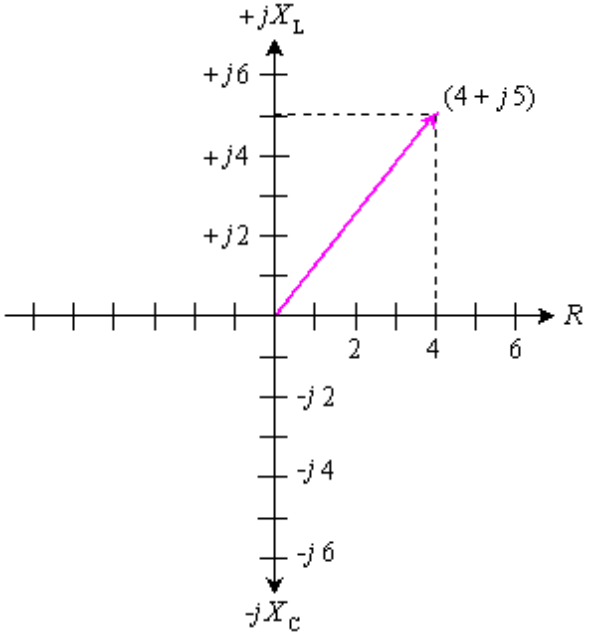
Patch



Horn

Antenna Basics
Impedance

Impedance (Z) : a vector consisting of resistance and reactance



Impedance: $Z = R \pm jX$

Resistance: R
Inductive: $+ jX_L$
Capacitive: $- jX_C$

Antenna Basics
Impedance

Antennna impedance

$Z_A = (R_L + R_r) \pm jX_A$

R_L = Dielectric and conducting losses in antenna and tranmission line
R_r = Radiation resistance for the antenna

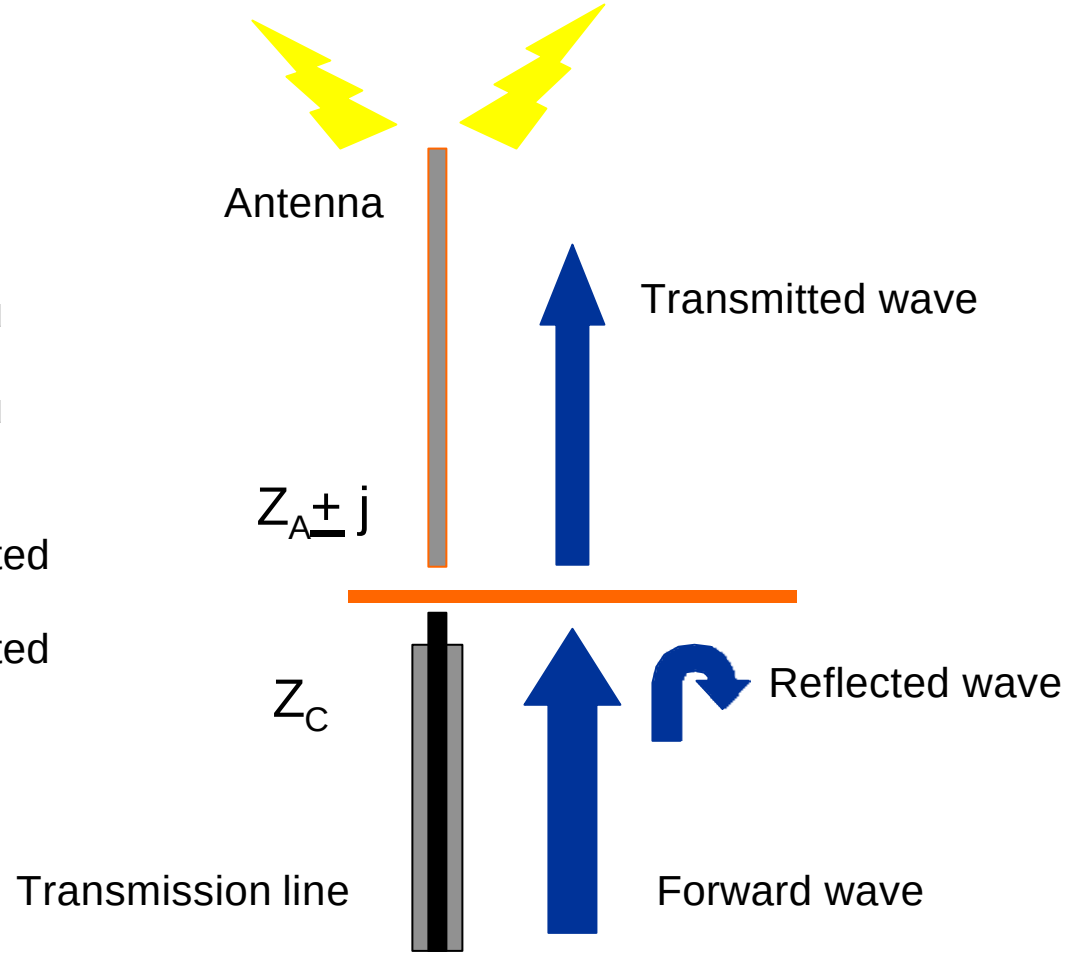
For an efficient transfer of energy, the impedance of the source, the antenna and transmission line connecting the source to the antenna must be the same. Traditionally they are designed for 50 Ohms impedance.

VSWR
Voltage Standing Wave Ratio

$$VSWR = \frac{U_{forward} + U_{Reflected}}{U_{forward} - U_{Reflected}}$$

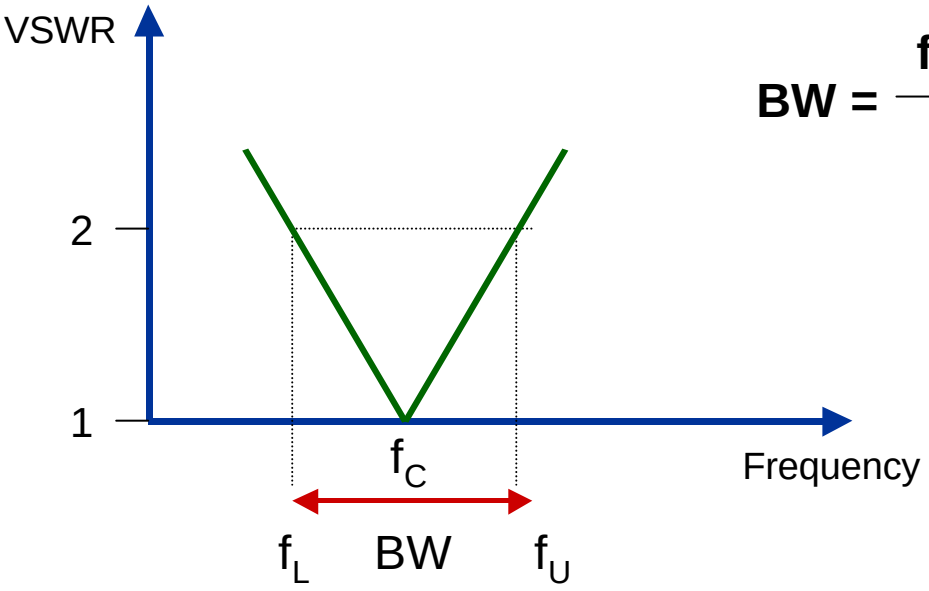
VSWR = 1:1 = >100% transmitted

VSWR = 2:1 => 89% transmitted



VSWR and BW

Voltage Standing Wave Ratio and Bandwidth



$$BW = \frac{f_U - f_L}{f_C} \times 100\%$$

f_C= Center frequency
f_L= Lower frequency
f_U= Upper frequency

Bandwith: the range of frequencies with acceptable antenna performance measured by one or more of the preformance parameters e.g. VSWR

Decibel (dB)

What's decibel dB?

Logarithmic expression of the ratio between two signal powers, voltages or current levels. Power amplitude difference in decibels, symbolized S_{dBP} is :

$$S_{dBP} = 10 \log (P_1 / P_2)$$

For voltages or currents, one uses 20 log X

dBi vs dBd

2.15dBi = 0dBd

Decibel relative an isotropic antenna, dBi
Gain of an antenna relative an isotropic radiator.

An isotropic radiator is theoretical ideal, radiates equally in all directions

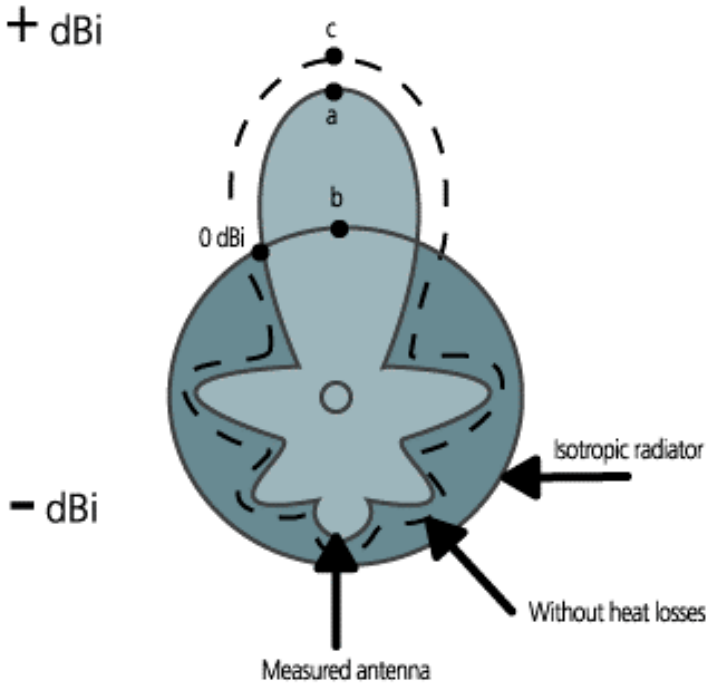
Decibel relative a dipole antenna, dBd
Gain of an antenna system relative a half-wave dipole

$$G[dBi] = G[dBd] + 2.15$$

Antenna Directivity

Directivity (D)

The ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions



Antenna Gain

Gain (G)

Directivity multiplied with the efficiency of the antenna

$$G_A = De_0 = e_0 \frac{U}{U_0} = e_0 \frac{4\eth U}{P_{rad}}$$

G_A = Gain of antenna

E_0 = Total efficiency

D = Directivity

U = Radiation intensity (W/unit solid angle)

U_0 = Radiation intensity of a isotropic source (W/unit solid angle**)**

P_{rad} = Total radiated power (W)

Radiation Parameters

Radiation Pattern measurement

Graphical representation of the field magnitude
at a fixed distance from an antenna as a function of direction
i.e. angular variation of the test antennas radiation.

Gain measurement

Absolute measurement that gives the angular variation of the test antenna's radiation. Needed to fully characterize the radiation properties of the test antenna.

Radiation Parameters

Polarization

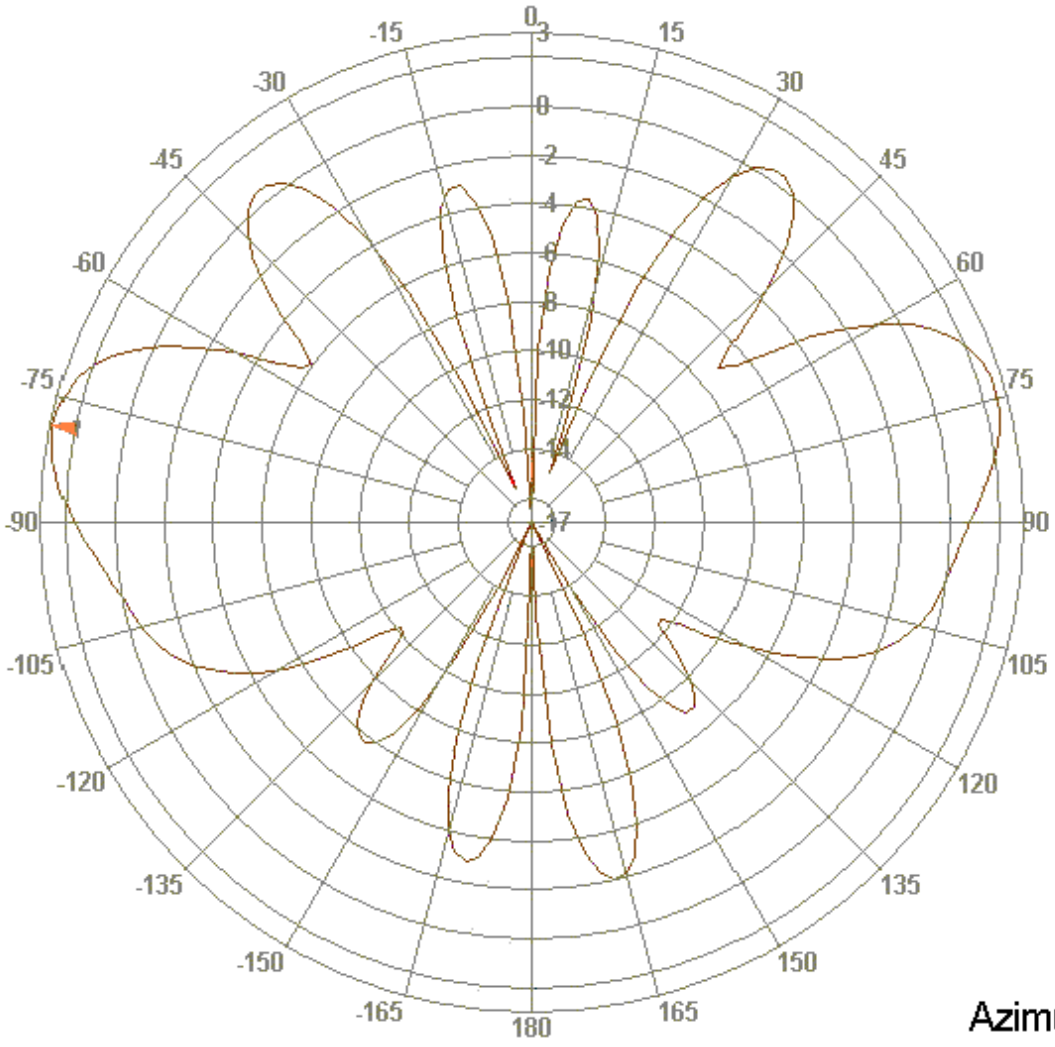
Defined as the polarization of the electromagnetic wave radiated by the antenna along a vector originating the antenna along the primary direction of propagation.

The direction of the oscillating electrical field vector
i.e. orientation of the E-filed.

Four basic types of polarization

Vertical-, horizontal-linear polarization and Left-hand elliptical, Right-hand elliptical polarization.

Radiation Parameters



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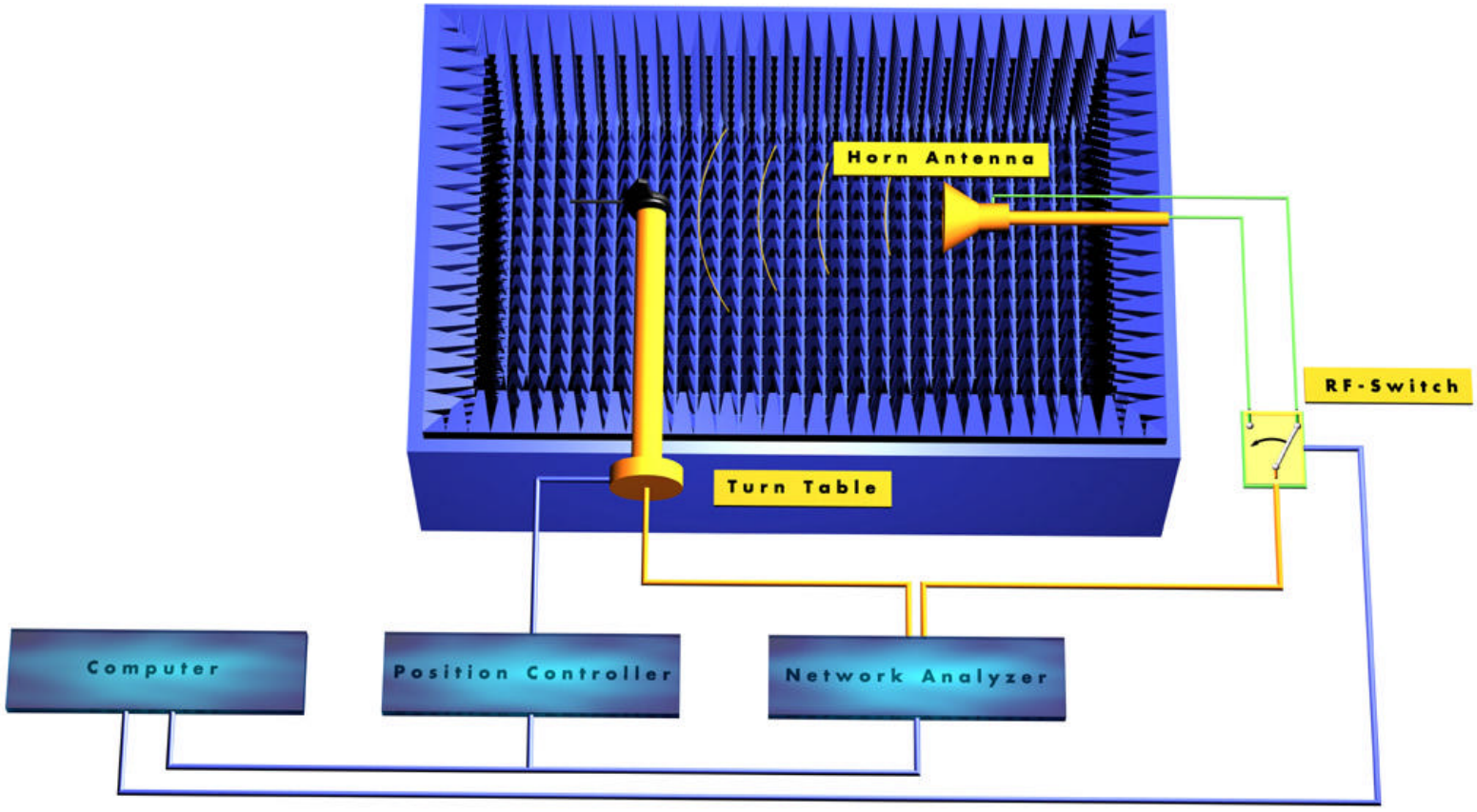
Anechoic chamber @ SMARTEQ

System overview



How do we evaluate/design a antenna in RF perspective?

- **Network Analyzer**
  - Input impedance
  - S-parameters
  - Transmission measurements
- **Antenna Range**
  - Radiation pattern
  - Gain
  - Polarization
- **Simulation Tools**
  - IE3D
  - HFSS
- **Live Measurement Systems**
  - TEMS
  - GPS dual reciver

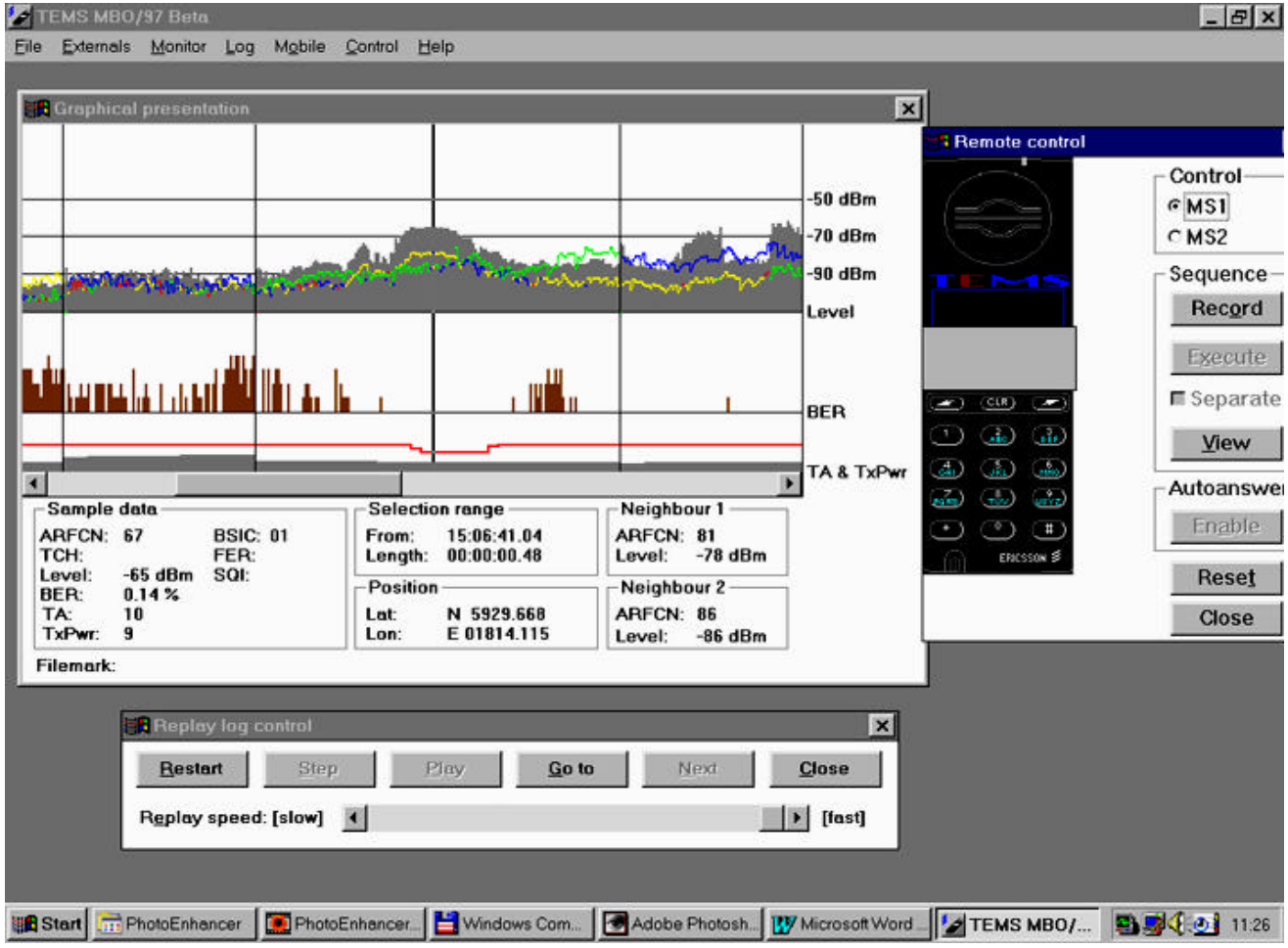
TEMS
TEst Mobile System

- Tems is a tool for verification and planning of cellular system
- It is a ”live” test system, two mobile phones and a laptop is combined
- The system monitors and saves/log the signaling between Mobile phone and Base station

Antenna testing using TEMS

- MS1 used with a reference antenna e.g. ¼-wave antenna mounted on the middle of the roof
- MS2 connected to the test antenna
- A call is set up between the Mobile phone’s during the test
- Several test routs is driven to monitor different RF-conditions
- Evaluation is performed comparing the two Mobile phone’s using a Smarteq developed program

TEMS
TEst Mobile System



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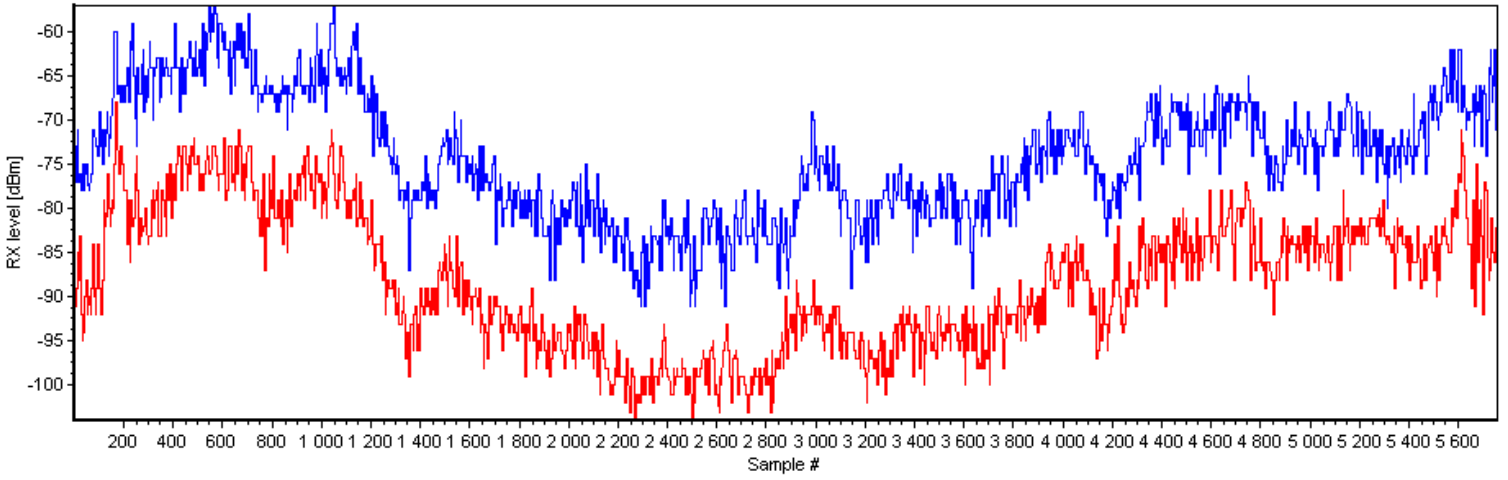
TEMS

External antenna vs. Mobile in talk position



file: 1104_5.fmt (SUBRX MS1) mean: -68.9 median: -74 98% percentile: -87 info: Smarteq GSM/GPS antenna

file: 1104_5.fmt (SUBRX MS2) mean: -82.1 median: -89 98% percentile: -101 info: Ericsson SH888 talk position

GPS, Global Positioning System

Do you know??

- You need **Three** satellites to get a position fix
- You need **Four** satellites to get the Clock/Time
- The satellite signals gets weaker further to the north, the satellite ”turn back” at 55 degrees north
- The GPS signals are very weak, -112dBm, a comunication system in the vicinity of the GPS system could cause it to fail,(GSM +33dBm)
- One orbit around the earth takes 11 hours and 57,97 minutes
- Smarteq GPS antennas are design/tested to work togheter with other communication systems
- Smarteq GPS antennas are tested to work mounted at an angel of 45 degrees